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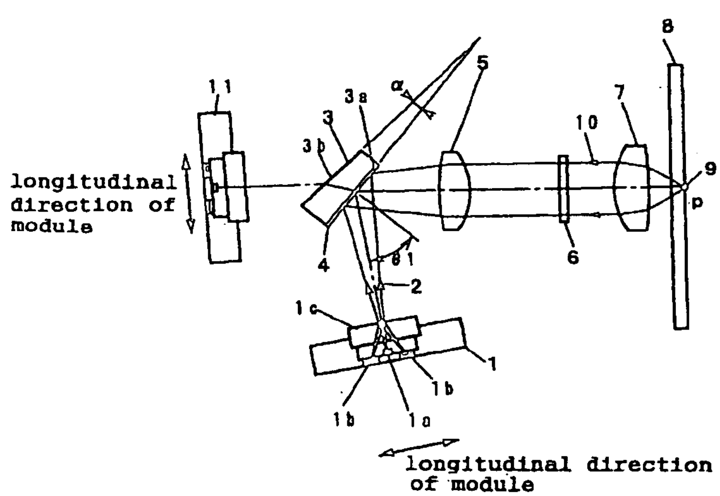
# (54) An optical head and an optical disk apparatus

(57) An optical head has a first light source; a second light source; a transmitting and reflecting means having a first surface and a second surface, and used to reflect diverging light from said first light source at said first surface, and to allow diverging light from said second light source to enter said second surface and to go out from said first surface, thereby to synthesize optical paths; an objective lens for converging light from said transmitting and reflecting means on an information recording surface of an optical disk and for condensing light reflected from said disk; and a photo-detector for receiving said reflected light, wherein said first surface and said second surface of said transmitting and reflecting means are not parallel to each other in order to decrease aberration when said diverging light from said second light source passes through said transmitting and reflecting means.

Fig. 1



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is used within a spread angle in the range of -7 to +7°, the compound prism 43 is configured so that the light beam 42 inside the glass of the compound prism 43 passes through the optical film 44 at least in the range of 45 - 4.6 to 45 + 4.6°. Therefore, since the s-polarized light passes through in the angle range, the light beam 42 entering as diverging light passes through the compound prism 43, and is condensed by a condenser lens 45 to become a nearly parallel light beam. The condensed light beam 42 is reflected by a mirror 46, passes through an aperture limitation means 47, and is focused on an image formation point p by an objective lens 48 to form a light spot 49 on the recording surface of the optical disk 8. This aperture limitation means 47 is configured so as to allow light with a wavelength of 650 nm to pass through totally, and so as to allow light with a wavelength of 780 nm to pass through only the internal portion thereof, which corresponds to a numerical aperture of 0.45. Furthermore, the objective lens 48 has a numerical aperture of 0.6, and is optimally designed for an optical disk having a substrate thickness of 0.6 mm. Therefore, the light beam 42 with a wavelength of 650 nm is focused in accordance with the numerical aperture of 0.6.

Next, a light beam 50 reflected by the optical disk 8 passes through the objective lens 48 and the aperture limitation means 47 again, is reflected by the mirror 46, and condensed by the condenser lens 45, and then enters the compound prism 43. In addition, the light beam 50 passes through the compound prism 43 and enters the first module 41. After entering the first module 41, the light beam 50 is diffracted by the hologram 41c, and enters a photo-detector 41b. The photo-detector 41b is configured to detect a focus control signal for making the objective lens 48 follow the recording surface by using the so-called SSD (spot size detection) method and to detect a tracking control signal for making the objective lens 48 follow the track on the track surface by using the phase contrast method.

Furthermore, the second module 51 is provided with a semiconductor laser 51a with a wavelength of 780 nm. Referring to FIG. 12, a light beam 52 with a wavelength of 780 nm emitted from the second module 51 passes through a hologram 51c, and enters the compound prism 43. Since the polarization direction of the light beam 52 is the longitudinal direction of the second module as shown in FIG. 15, the light beam 52 enters the compound prism 43 as s-polarized light. Therefore, the light beam 52 is reflected by the optical film 44 having the characteristics shown in FIGS. 16a, 16b and 16c, and condensed by the condenser lens 45 to become slightly diverging light. After reflected by the mirror 46, the light beam 52 passes through only the internal portion of the aperture limitation means 47, which corresponds to a numerical aperture of 0.45. The light beam then enters the objective lens 48, and is focused on an image formation point p' to form a light spot 53 on the recording surface of the optical disk 13. By limiting the aperture, the numerical aperture is set to 0.45, whereby this configuration can be made compatible with the optical disk 13 having a substrate thickness of 1.2 mm, such as CD.

A light beam 54 reflected by the optical disk 13 passes through the objective lens 48, the aperture limitation means 47 and the mirror 46 again, and is condensed by the condenser lens 45, and then enters the compound prism 43. Most of the light beam 54 is reflected and enters the second module 51. After entering the second module 51, the light beam 54 is diffracted by the hologram 51c, and enters a photo-detector 51b. The photo-detector 51b is configured to detect a focus control signal for making the objective lens 48 follow the recording surface by using the SSD method and to detect a tracking control signal for making the objective lens 48 follow the track on the track surface by using the push-pull method. Although the three-beam method is generally used to detect the tracking control signal for CD, the push-pull method is used in the conventional example in order to simplify explanations.

In the case that the high-density optical disk 8 compatible with a wavelength of 650 nm is played back by using the above-mentioned optical system, the semiconductor laser 41a is lit, its light beam is focused on the optical disk 8, and a light beam reflected by the optical disk 8 is received by the photo-detector 41b, whereby reproduction and control signals can be obtained. In the case that the optical disk 13 compatible with a wavelength of 780 nm is played back, the semiconductor laser 51a is lit, its light beam is focused on the optical disk 13, and a light beam reflected by the optical disk 13 is received by the photo-detector 51b, whereby reproduction and control signals can be obtained. In this way, the two types of optical disks 8 and 13 being different in thickness and wavelength compatibility can be played back.

In the above-mentioned optical head, the light beam 42 is diverging light and has a spread angle in the range of about -7 to +7°. The spread angle in the range of -7 to +7° in the air corresponds to a spread angle in the range of -4.6 to +4.6° in glass. Therefore, the optical film 44 is required to have characteristics of allowing s-polarized light with a wavelength of 650 nm to pass through in the range of 45 - 4.6° to 45 + 4.6° and also allowing s-polarized light with a wavelength of 780 nm to be reflected, thereby requiring the characteristics shown in FIGS. 16a, 16b and 16c. These characteristics can be used only for s-polarized light. Even if wavelength characteristics are optimized, the positional relationship in the optical head cannot be arranged so that p-polarized light enters the compound prism 43.

When explained again, in the above-mentioned conventional art, the light beam emitted from the second module 51 for CD playback enters the compound prism 43 as s-polarized light. The polarization direction (direction of electric field) of the light beam is the longitudinal direction of the second module 51 as shown in FIG. 15. Therefore, the module of the optical head is forced to be arranged as shown in FIG. 11 because of the wavelength characteristics of the optical film 44 shown in FIGS. 16a, 16b and 16c.

In other words, the components of the optical head, that is, the module 41, the module 51, the prism 43, the optical film 44, the condenser lens 45, the mirror 46, the aperture limitation means 47 and the objective lens 48, are forced to

and second surfaces of said transmitting and reflecting means; and a second photo-detector for receiving said reflected light with said second wavelength after reflection at said first surface of said transmitting and reflecting means, wherein said first surface and said second surface of said transmitting and reflecting means are not parallel to each other in order to decrease aberration when said diverging light from said first light source passes through said transmitting and reflecting means.

In other words, by forming an optical film for synthesizing and separating diverging light from CD and diverging light from DVD on a prism having an apex angle allowing aberration to decrease when diverging light passes through, the polarized light separation width of the optical film can be made smaller, whereby light beams with two wavelengths can be synthesized and separated regardless whether polarized light is p-polarized light or s-polarized light. Therefore, in accordance with the present invention, in an optical system wherein a condenser lens and an objective lens are made usable for the two wavelengths, the optical system can be configured regardless of the polarization direction from the light source, whereby the optical head can be made thinner.

Consequently, a single optical head can be used for optical disks having different substrate thicknesses or optical disks compatible with different wavelengths. Therefore, recording and reproduction are made possible on DVD optical disks having high density attained by increasing the numerical aperture of the objective lens, on the conventional optical disks having a substrate thickness of 1.2 mm, on disks having high density and being compatible with a short wavelength attained by shortening the wavelength of a semiconductor laser for recording and reproduction, and on disks compatible with the conventional wavelength.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view showing a configuration partially modified from that of an embodiment shown in FIG. 3;
FIG. 2 is a view showing a configuration partially modified from that of an embodiment shown in FIG. 4;
FIG. 3 is a perspective view showing the configuration of an optical head in accordance with a first embodiment of the present invention;
FIG. 4 is a perspective view showing the configuration of the optical head in accordance with the first embodiment of the present invention;
FIGS. 5a, 5b and 5c are graphs showing the characteristics of an optical film in accordance with the first embodiment of the present invention;
FIG. 6 is an explanatory view showing an aperture limitation means in accordance with the first embodiment of the present invention;
FIGS. 7a, 7b and 7c are graphs showing the characteristics of a design example of the optical film in accordance with the first embodiment of the present invention;
FIG. 8 is a view showing the configuration of an optical head in accordance with a second embodiment of the present invention;
FIG. 9 is a view showing the configuration of the optical head in accordance with the second embodiment of the present invention;
FIG. 10 is an explanatory view showing a polarization hologram in accordance with the second embodiment of the present invention;
FIG. 11 is a view showing the configuration of a conventional optical head;
FIG. 12 is a view showing the configuration of the conventional optical head;
FIG. 13 is a perspective view showing the conventional optical head shown in FIG. 11;
FIG. 14 is a perspective view showing the conventional optical head shown in FIG. 12;
FIG. 15 is an explanatory view showing the module of the conventional optical head; and
FIGS. 16a, 16b and 16c are graphs showing the characteristics of the optical film of the conventional optical head.

## PREFERRED EMBODIMENTS

Embodiments of the present invention will be described below referring to the accompanying drawings.

### (First embodiment)

The configuration and operation of an optical head in accordance with a first embodiment of the present invention will be described below referring to the drawings. FIGS. 3 and 4 are perspective views showing the configuration of the optical head in accordance with the first embodiment of the present invention. FIGS. 1 and 2 are schematic views wherein an optical disk 8, an objective lens 7 and an aperture limitation means 6 are temporarily disposed on a plane formed by a first module 1, a second module 2, a prism 3 and a condenser lens 5, with a mirror 14 omitted from FIGS. 3 and 4. FIGS. 1 and 3 show a condition wherein a high-density optical disk 8 having a substrate thickness of 0.6 mm

pull method. Although the push-pull method is used in the present embodiment just as in the case of the conventional example in order to simplify explanations, the three-beam method having been used generally may be used.

In the case of the optical head in accordance with the present embodiment, in an optical system wherein the light beam has a wavelength of 650 nm, the optical disk has a substrate thickness of 0.6 mm, the objective lens 7 is designed to have a numerical aperture of 0.6, and the focal lengths of the object lens 7 and the condenser lens 5 are 3 mm and 25 mm, respectively, by properly setting the distance from the semiconductor laser 11a to the condenser lens 5, a light beam with a wavelength of 780 nm can be converged on the optical disk 13 having a substrate thickness of 1.2 mm at a wavefront aberration of 10 m$\lambda$ or less. In the present embodiment, the distance from the semiconductor laser 11a to the condenser lens 5 is made shorter than the distance from the semiconductor laser 1a to the condenser lens 5 by about 8 mm. With this configuration, the optical disk 13 having a substrate thickness of 1.2 mm can be played back by using the light beam 12 without problems.

In the case that the high-density optical disk 8 compatible with a wavelength of 650 nm is played back by using the above-mentioned optical head, the semiconductor laser 1a is lit, its light beam is focused on the optical disk 8, and the light beam reflected from the disk is received by the photo-detector 1b to obtain reproduction and control signals. In addition, in the case that the optical disk 13 compatible with a wavelength of 780 nm is played back, the semiconductor laser 11a is lit, its light beam is focused on the optical disk 13, and the light beam reflected from the disk is received by the photo-detector 11b to obtain reproduction and control signals.

In the above-mentioned configuration, since the light beam 2 is cast from the air side to the glass side of the prism 3, the polarized light separation width ($\Delta$H in FIG. 5) between p-polarized light and s-polarized light becomes smaller than that of the conventional prism in which the light beam enters from one glass side to the other glass side thereof. Furthermore, the $\Delta$H can be made smaller even further by decreasing the incident angle $\theta 1$ of the light beam 2 with respect to the center of optical axis. When the incident angle $\theta 1$ is 39 degrees, and the optical film 4 is designed so as to comprise alternate layers of TiO2 and SiO2, for example, results listed in Table 1 can be obtained. It is assumed that the refractive index of the substrate for the prism 3 is 1.5, and that the optical film thickness is obtained by multiplying the physical film thickness by refractive index.

[Table 1]

| Example of configuration of optical film 4 | | | |
|---|---|---|---|
| (Design wavelength $\lambda$ = 680/4 nm) | | | |
| | Material | Refractive index | Optical film thickness |
| Layer 1 | $TiO_2$ | 2.25 | 0.60 $\lambda$ |
| Layer 2 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 3 | $TiO_2$ | 2.25 | 0.90 $\lambda$ |
| Layer 4 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 5 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 6 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 7 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 8 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 9 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 10 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 11 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 12 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 13 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 14 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 15 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |
| Layer 16 | $SiO_2$ | 1.46 | 1.00 $\lambda$ |
| Layer 17 | $TiO_2$ | 2.25 | 1.00 $\lambda$ |

(Second embodiment)

The configuration and operation of an optical head in accordance with a second embodiment of the present invention will be described below referring to the drawings. FIGS. 8 and 9 are views showing the configuration of the optical head in accordance with the second embodiment of the present invention. FIG. 8 shows a condition wherein a high-density optical disk 8 having a substrate thickness of 0.6 mm is played back in accordance with the present embodiment, and FIG. 9 shows a condition wherein an optical disk 13 having a substrate thickness of 1.2 mm is played back. Referring to FIG. 8, a first module 21 for DVD playback is an integrated combination of a semiconductor laser 21a with a wavelength of 650 nm and a photo-detector 21b for receiving light reflected from the disk. In both FIGS. 8 and 9, all components are disposed on a plane perpendicular to the optical disks 8 and 13 in order to simply explanation.

A light beam 22 with a wavelength of 650 nm emitted from the semiconductor laser 21a of the first module 21 passes through a polarization hologram 23 and a quarter-wave plate 24 and becomes circularly polarized light. Diverging light having become the circularly polarized light enters a prism 25 at incident angle θ1 at the center of the optical axis. Since the prism 25, the first module 21 and a second module 32 are disposed on the same plane, the longitudinal directions of the modules are the directions shown in FIGS. 8 and 9. As a result, p-polarized light enters the polarization hologram 23. An optical film 26 comprising dielectric multilayers is formed on the prism 25 as shown in FIG. 3. The prism 25 and the optical film 26 may be the same as those used in the above-mentioned first embodiment. The light beam 22 having become the circularly polarized light is reflected by the optical film 26 and condensed by a condenser lens 27 and becomes a nearly parallel light beam, and enters an aperture limitation means 28. The aperture limitation means 28 is formed of optical multilayers, wherein the characteristics of the optical multilayer at the internal portion differ from those of the optical multilayer at the external portion. The internal portion allows light with a wavelength of 650 nm and light with a wavelength of 780 nm to pass through; and the external portion allows light with a wavelength of 650 nm to pass through, and allows light with a wavelength of 780 nm to be reflected. Therefore, the light beam 22 with a wavelength of 650 nm can pass through both the internal and external portions of the aperture limitation means 28. The numerical aperture of the objective lens 29 is set at 0.6 so as to be compatible with high-density optical disks, such as DVD. After entering the objective lens 29, the light beam 22 is focused on an image formation point p to form a light spot 30 on the recording surface of the optical disk 8 having a substrate thickness of 0.6 mm. Next, a light beam 31 reflected by the optical disk 8 passes through the objective lends 29 and the aperture limitation means 28 again, is condensed by the condenser lens 27, and enters the prism 25. The light beam 31 with a wavelength of 650 nm is reflected by the optical film 26 formed on the prism 25, and is converted into linearly polarized light perpendicular to the light beam 22 by the quarter-wave plate 24, and enters the polarization hologram 23. The polarization hologram 23 is made by forming a hologram on a LiNb substrate formed of complex refraction materials by proton exchange, and is configured to allow extraordinary light to pass through and to allow ordinary light to be diffracted. By using the light beam 22 as extraordinary light, and by using the light beam 31 as ordinary light, the light beam 22 is allowed to pass through, and the light beam 31 is allowed to be diffracted. The diffracted light beam 31 passes through the cover glass 21c of the first module 21 and enters the photo-detector 21b. The photo-detector 21b detects a focus control signal for making the objective lens 29 follow the recording surface by using the SSD method, and detects a tracking control signal for making the objective lens 29 follow the track on the track surface by using the phase contrast method.

Referring to FIG. 9, a light beam 33 with a wavelength of 780 nm emitted from the second module 32 passes through the hologram 32c, and enters the prism 25 at incident angle θ2. Since the direction of polarization is the longitudinal direction of the module, the light beam 33 enters the prism 25 as p-polarized light, is refracted at the surface of the prism and goes out so as to have the same optical path as that of the light beam 22. The optical film 26 formed on the prism 25 allows both the p-polarized light and the s-polarized light of the light beam with a wavelength of 780 nm to pass through because of the characteristics shown in FIGS. 5a, 5b and 5c. Therefore, the light beam 33, that is, p-polarized light, passes through the optical film 26, and is condensed by the condenser lens 27 so as to become slightly diverging light. By using the aperture limitation means 28, the condensed light beam 33 passes through only the internal portion of the aperture limitation means 28, corresponding to a numerical aperture of 0.45, enters the objective lens 29, and is focused on an image formation point p' to form a light spot 34 on the recording surface of the optical disk 13. By the aperture limitation, the optical head is made compatible with the optical disk 13 having a substrate thickness of 1.2 mm, such as CD.

A light beam 35 reflected by the optical disk 13 passes through the objective lends 29 and the aperture limitation means 28 again, is condensed by the condenser lens 27 and enters the prism 25. The light beam 35 with a wavelength of 780 nm passes through the prism 25 and enters the second module 32. After entering the second module 32, the light beam 35 is diffracted by the hologram 32c and enters the photo-detector 32b. The photo-detector 32b is configured to detect a focus control signal for making the objective lens 29 follow the recording surface by using the SSD method and to detect a tracking control signal for making the objective lens 29 follow the track on the track surface by using the push-pull method.

In the case that the high-density optical disk 8 compatible with a wavelength of 650 nm is played back by using the

2. An optical head used with optical disks having two different substrate thicknesses, comprising a first light source for emitting light with a first wavelength; a second light source for emitting light with a second wavelength; a transmitting and reflecting means having a first surface and a second surface, and used to reflect diverging light from said first light source at said first surface, and to allow diverging light from said second light source to enter said second surface and to go out from said first surface, thereby to synthesize optical paths; an objective lens for converging said light with said first wavelength on an information recording surface of one optical disk having a smaller substrate thickness, for converging said light with said second wavelength on an information recording surface of the other optical disk having a larger substrate thickness, and for condensing light reflected from said optical disks; a first photo-detector for receiving said reflected light with said first wavelength after reflection by said first surface of said transmitting and reflecting means; and a second photo-detector for receiving said reflected light with said second wavelength after passing through said first and second surfaces of said transmitting and reflecting means, wherein said first surface and said second surface of said transmitting and reflecting means are not parallel to each other in order to decrease aberration when said diverging light from said second light source passes through said transmitting and reflecting means.

3. An optical head used with optical disks having two different substrate thicknesses, comprising a first light source for emitting light with a first wavelength; a second light source for emitting light with a second wavelength; a transmitting and reflecting means having a first surface and a second surface, and used to allow diverging light from said first light source to enter said second surface and to go out from said first surface, and to reflect diverging light from said second light source at said first surface, thereby to synthesize optical paths; an objective lens for converging said light with said first wavelength on an information recording surface of one optical disk having a smaller substrate thickness, for converging said light with said second wavelength on an information recording surface of the other optical disk having a larger substrate thickness and for condensing light reflected from said optical disks; a first photo-detector for receiving said reflected light with said first wavelength after passing through said first and second surfaces of said transmitting and reflecting means; and a second photo-detector for receiving said reflected light with said second wavelength after reflection at said first surface of said transmitting and reflecting means, wherein said first surface and said second surface of said transmitting and reflecting means are not parallel to each other in order to decrease aberration when said diverging light from said first light source passes through said transmitting and reflecting means.

4. An optical head in accordance with claim 2 or 3, further comprising an aperture limitation means for limiting an aperture for said light with said second wavelength.

5. An optical head in accordance with claim 4, wherein said aperture limitation means limits said aperture for said light with said second wavelength so that the numerical aperture thereof is set at 0.45.

6. An optical head in accordance with one of claims 2 to 5, wherein said objective lens is configured to decrease aberration when said light with said first wavelength is converged on the information recording surface of said optical disk having said smaller substrate thickness, and said second light source is disposed at a position where aberration decreases when said light with said second wavelength is converged on the information recording surface of said optical disk having said larger substrate thickness.

7. An optical head in accordance with one of claims 2 to 6, wherein said optical disk having said smaller substrate thickness has a thickness of substantially 0.6 mm, and said optical disk having said larger substrate thickness has a thickness of substantially 1.2 mm.

8. An optical head in accordance with one of claims 2 to 7, wherein said first wavelength has a value between 620 nm and 670 nm, and said second wavelength has a value between 760 nm and 850 nm.

9. An optical head in accordance with one of claims 1 to 8, wherein said transmitting and reflecting means comprises a transparent member and an optical film disposed on one surface of said transparent member; the transmittance of said optical film is substantially 0% for the s-polarized light and p-polarized light of incident light having a wavelength within a specified range, and is substantially 100% for the s-polarized light and p-polarized light of incident light having a wavelength within another specified range; and said optical film is disposed on said first surface.

10. An optical head in accordance with one of claims 1 to 9, wherein the angle between said first surface and said second surface is set at 2 ± 1°.

Fig. 1

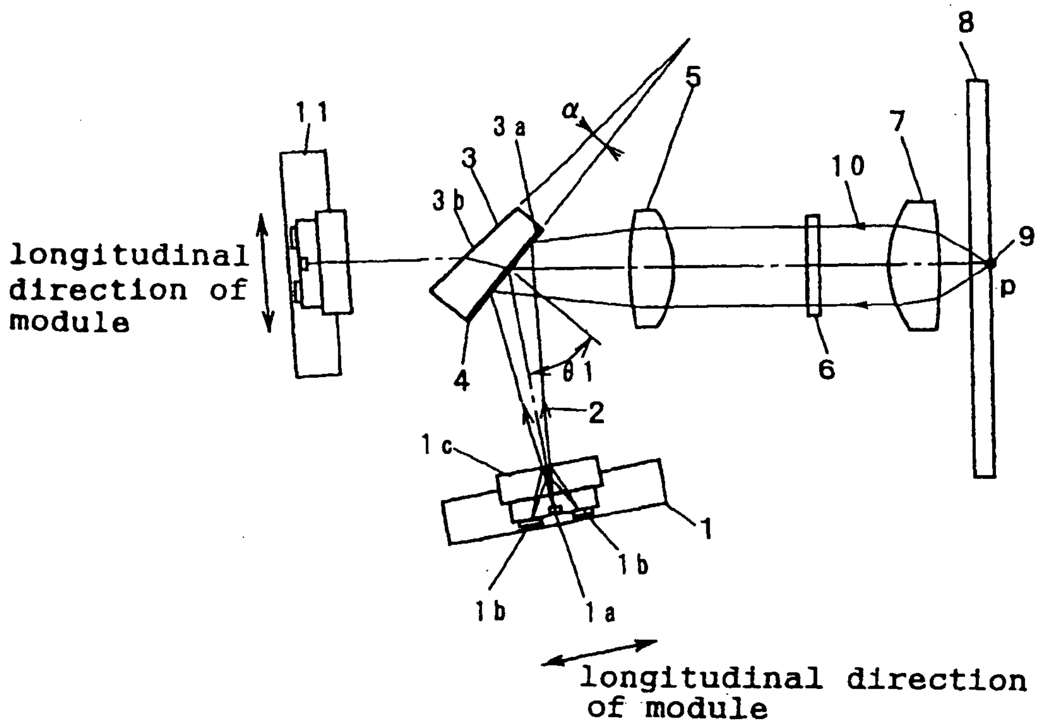

8
11
3a
α
5
7
3
10
3b
9
longitudinal
direction of
module
p
θ1
4
6
2
1c
1
1b
1b
1a
longitudinal direction
of module

Fig. 2

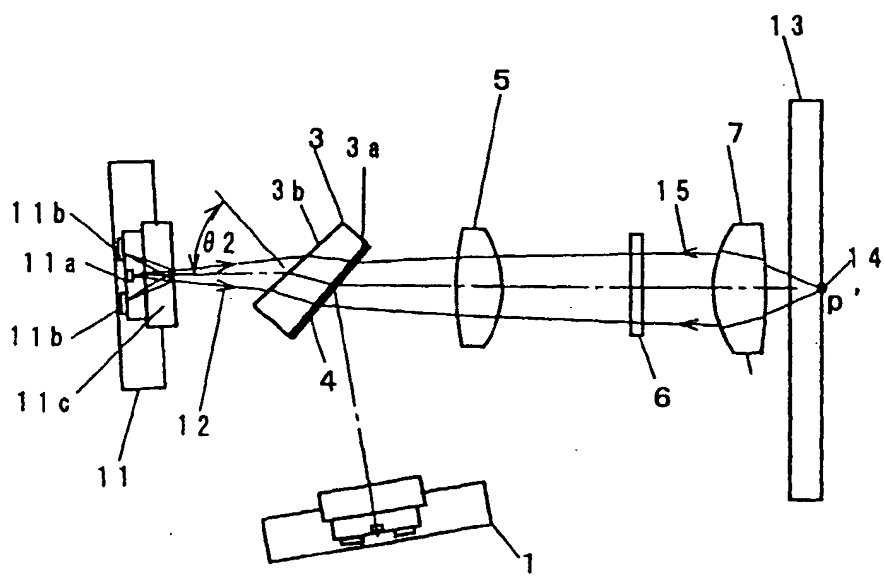

13
5
3
3a
7
3b
15
11b
θ2
14
11a
p'
11b
4
6
11c
12
11
1

Fig. 5 (a)

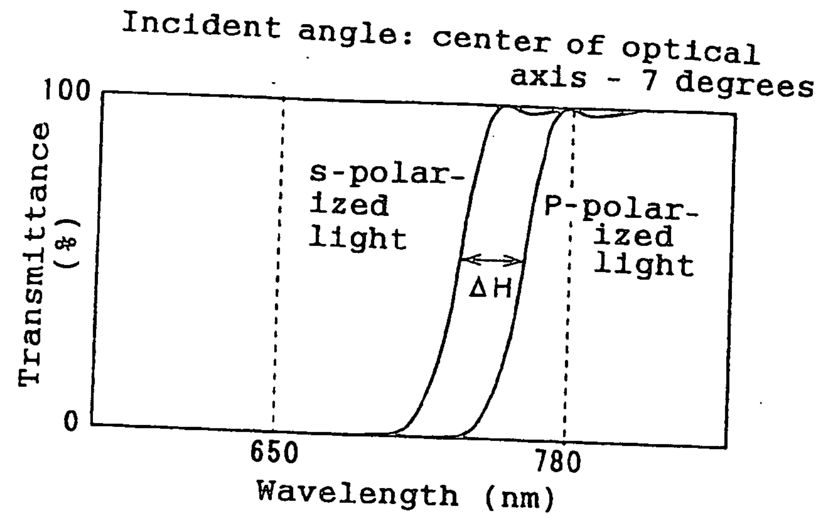



Fig. 5 (b)

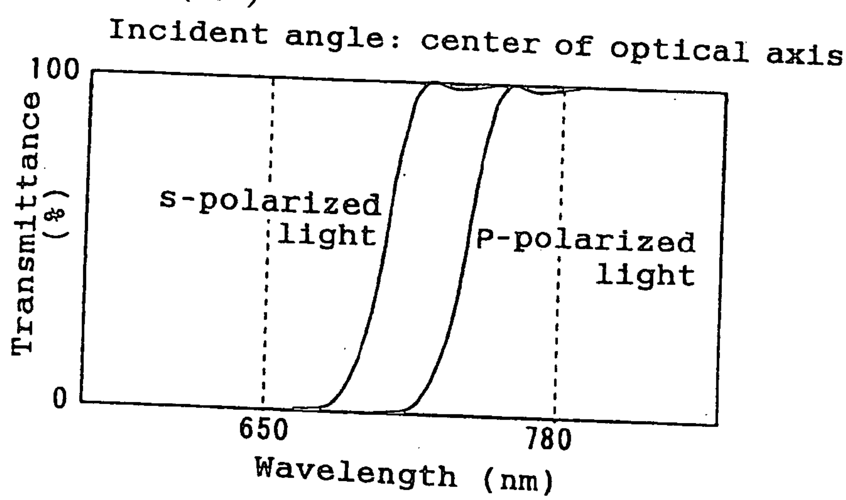



Fig. 5 (c)

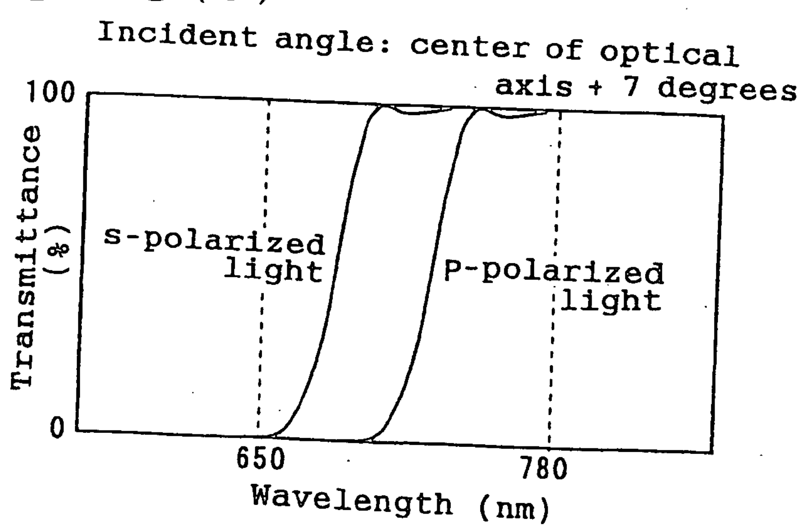


Fig. 7 (a)

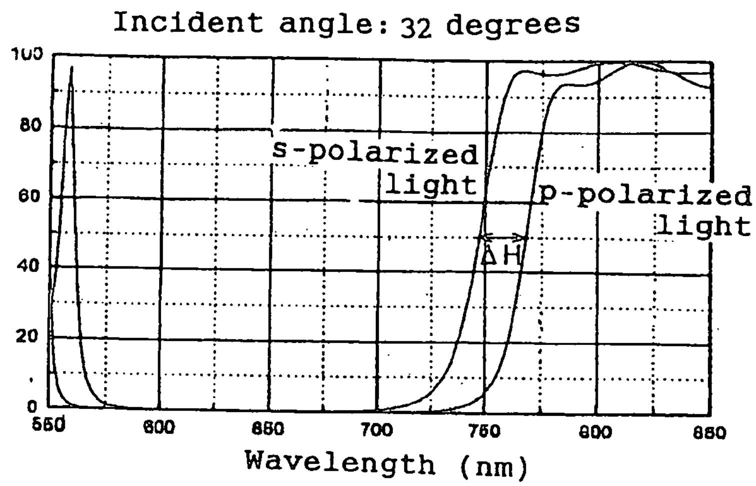



Fig. 7 (b)

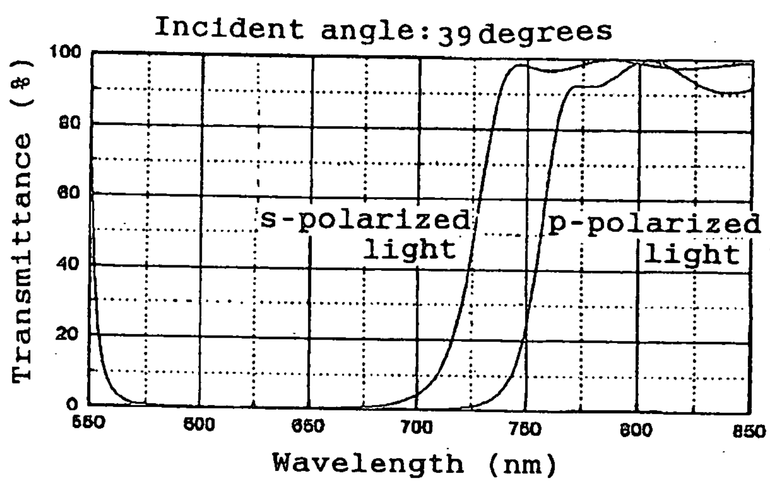



Fig. 7 (c)

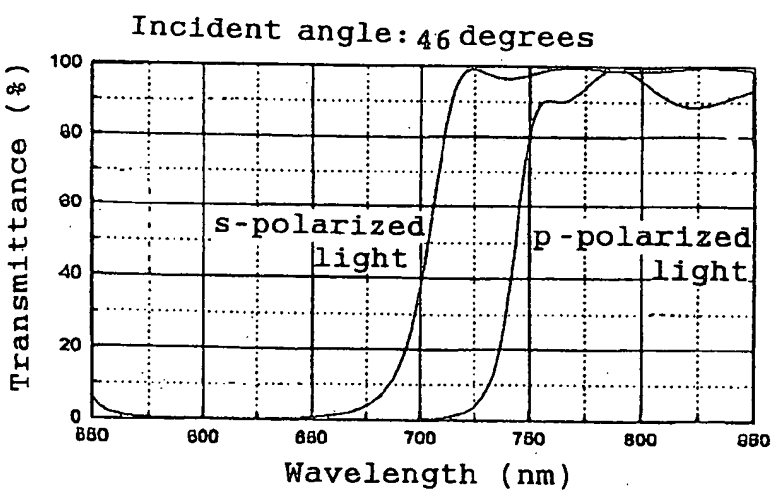


Fig. 10

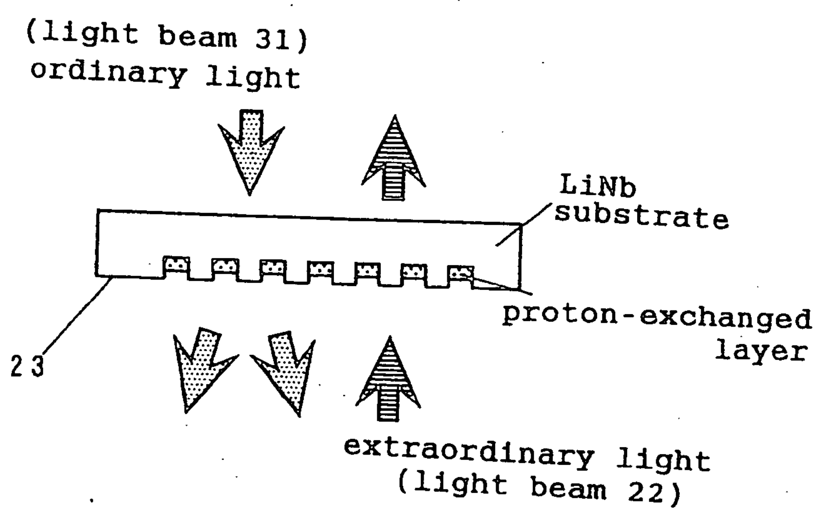

(light beam 31)
ordinary light
LiNb
substrate
proton-exchanged
layer
23
extraordinary light
(light beam 22)

Fig. 13 PRIOR ART

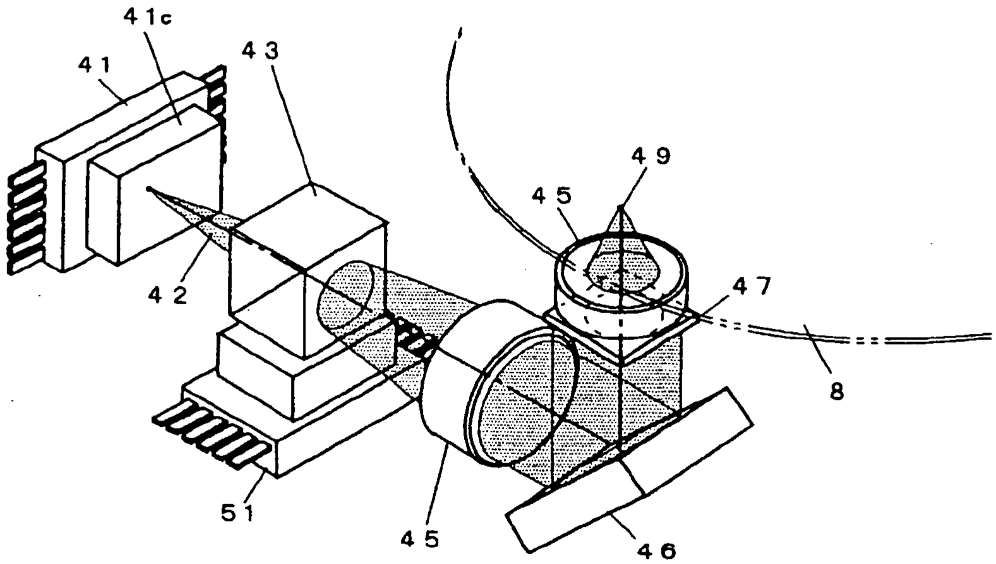



Fig. 14 PRIOR ART

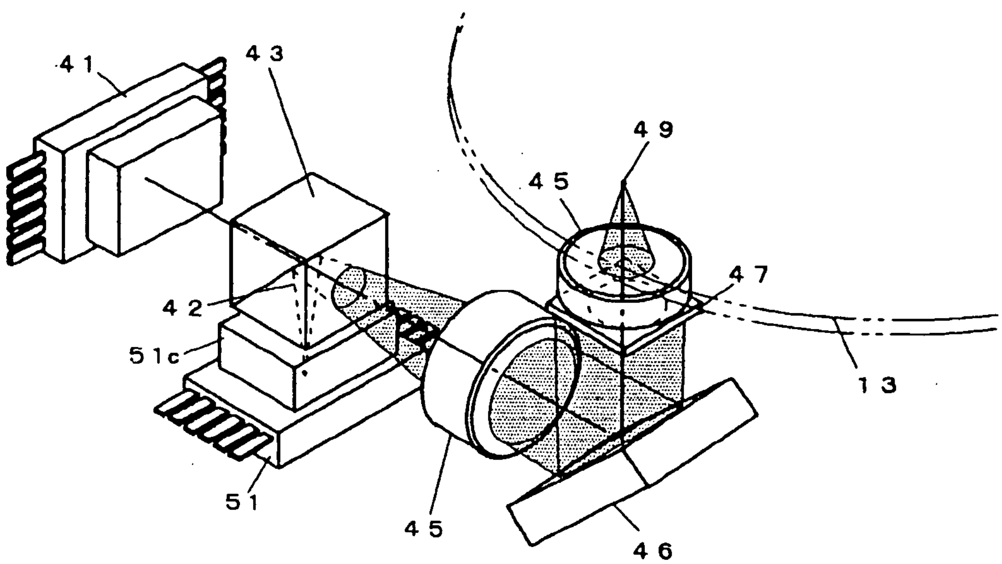


Fig. 16(a) PRIOR ART

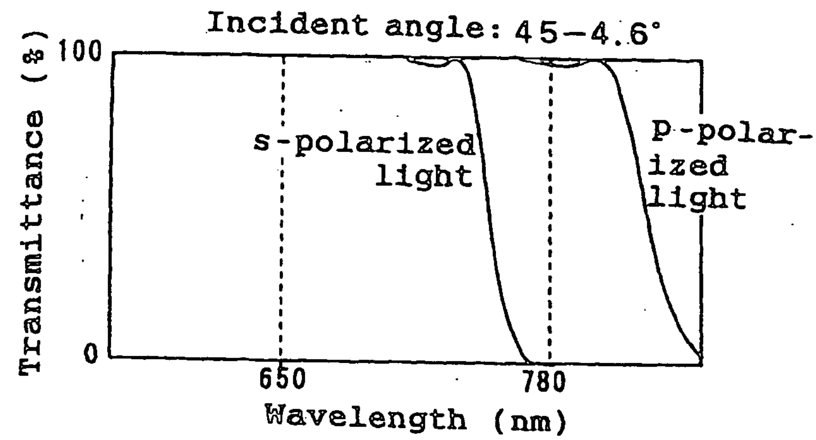



Fig. 16(b) PRIOR ART

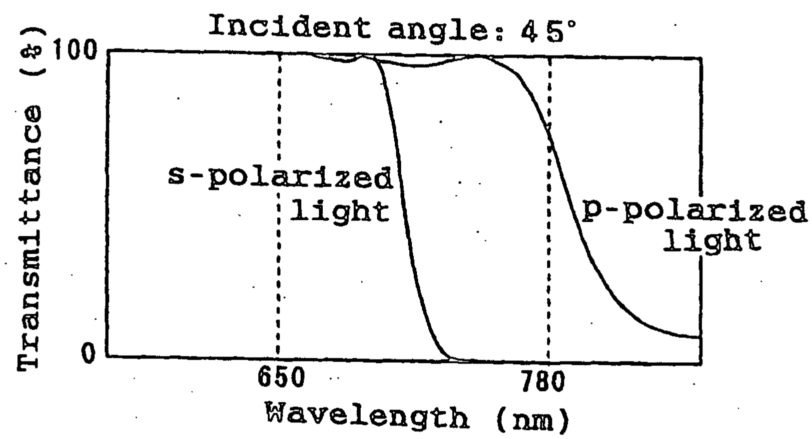
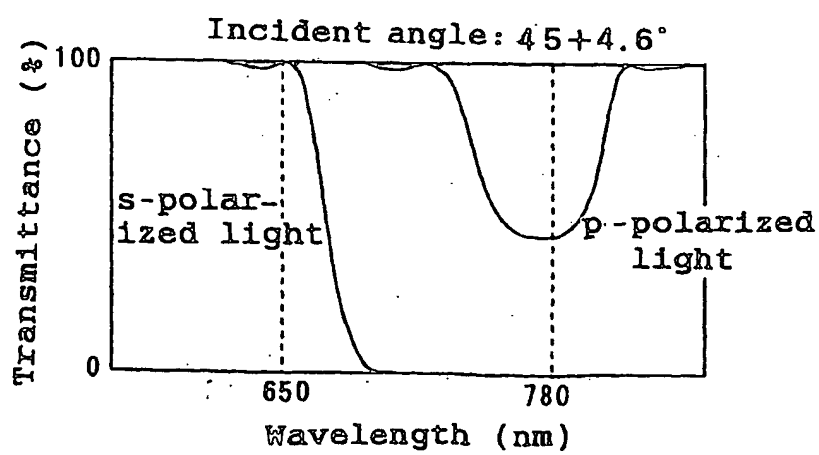



Fig. 16(c) PRIOR ART



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European Patent Office
Office européen des brevets

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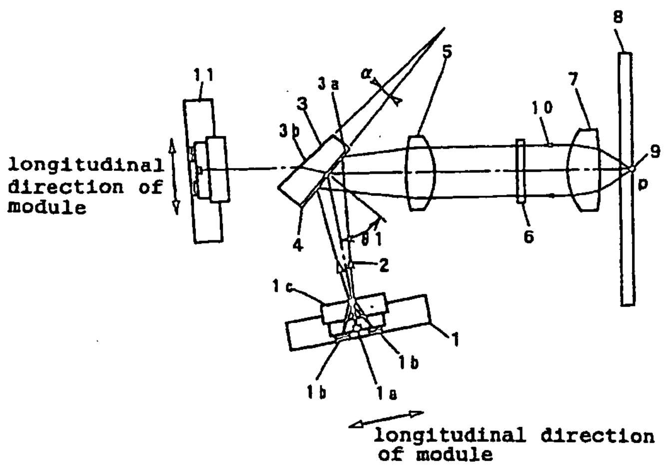
(54) An optical head and an optical disk apparatus

(57) An optical head has a first light source; a second light source; a transmitting and reflecting means having a first surface and a second surface, and used to reflect diverging light from said first light source at said first surface, and to allow diverging light from said second light source to enter said second surface and to go out from said first surface, thereby to synthesize optical paths; an objective lens for converging light from said transmitting and reflecting means on an information recording surface of an optical disk and for condensing light reflected from said disk; and a photo-detector for receiving said reflected light, wherein said first surface and said second surface of said transmitting and reflecting means are not parallel to each other in order to decrease aberration when said diverging light from said second light source passes through said transmitting and reflecting means.

Fig. 1

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